As we measure an object moving past us, we measure its length to
1. increase.
2. decrease.
3. I'm going to say increase but I think this is baloney.
4. I'm going to say decrease but only so I don't flunk the exam.

By these things we know that there is a God in heaven, who is infinite and eternal, from everlasting to everlasting the same unchangeable God, the framer of heaven and earth, and all things which are in them.

~ D & C 20:17

Dynamic Events
We observe many dynamic events in nature where obvious changes take place.
- earthquakes
- volcanoes, etc.

Question: Are there some things (quantities) that do not change?

Answer: Yes. Some quantities are "conserved" even in times of violent change. Furthermore, the quantities that do change, do so in ways predicted by principles that do not change.

What do we mean by a conserved quantity?
A conserved quantity:
- is measurable
- may change form
- has the same total amount before and after the event

Have you read chapter 8
- Yes
- No
Conservation

A few fundamental quantities are **conserved**. That is, they neither increase nor decrease with time. They are:
- Mass
- Total charge
- # of fundamental particles
- Linear momentum
- Angular momentum
- Total energy

Non-conservation

To contrast, these quantities are **not conserved**.
- Temperature
- Force
- Kinetic energy
- Potential energy
- Internal energy
- Order

Conservation of Mass

Mass is neither created nor destroyed. But it can change form or state. (Mostly)

Conservation of Fundamental Particles

Fundamental building blocks of matter are conserved.
- Leptons (electrons)
- Quarks (protons, neutrons)

Conservation of Charge

Rubbing a balloon on your head does not create charge, but simply redistributes existing charge.
- Negative charge goes to the balloon leaving your hair positively charged
- We assume the total charge of the universe is zero.

Conservation of Linear Momentum

Momentum = \( p = m \times v \) (Note: velocity has a direction and so does momentum)
- The momentum before a collision must equal the momentum after a collision.
If a cue ball hits a billiard ball, can the cue bounce straight back leaving the other ball motionless?

1. Yes
2. No
3. Only if the cue hits straight on.

Assume they both have the same mass, neither ball is touching a wall, and the cue ball isn’t spinning in some weird way.

Conservation of Linear Momentum

- When a firecracker explodes in midair, the path of the center of the explosion is exactly the same as the path the firecracker would have followed if it had never exploded.

Boatman video
Pool video

Conservation of Linear Momentum at Very High Speeds

From the point of view of the astronauts there is no momentum before the explosion, and equal and opposite momentum after.

Conservation of Linear Momentum at Very High Speeds
From the point of view of ground control the explosion stops the explosion ½ of the object but the other half is NOT moving twice as fast! At face value this violates conservation of momentum.

What gives?

Mass Increases at High Speed!

\[ p = m \times v \]

- Either momentum is not conserved at high speeds or mass is not conserved.
  - Conservation of momentum follows from position symmetry (Noether’s theorem). This makes it very solid.
  - Mass, as it turns out, is not conserved by itself. Instead it is conserved together with energy by the relation \( E = mc^2 \). More on this next time.

Conservation of Angular Momentum

- Angular momentum = \( m \times v \times \mathbf{r} \)
- Because of the conservation of angular momentum, divers can control their rotational velocity by tucking their limbs.

Demos: orbiting ball, “The Chair”
Video: skater